E-82

BRL

CONTRACT 169

REPORT NO. 4

UPPER ATMOSPHERE WINDS FROM GUN LAUNCHED VERTICAL PROBES

(Yuma, 13-15 June 1966)

SPACE INSTRUMENTS RESEARCH, INC.

41

BRL CONTRACT 169 REPORT 4

UPPER ATMOSPHERE WINDS FROM GUN LAUNCHED VERTICAL PROBES

(Yuma 13-15 June 1966)

Prepared by:

Robert N. Fuller
Research Physicist

Approved by:

Howard D. Edwards
Technical Director

Space Instruments Research, Inc.
Atlanta, Georgia

December 1966

TABLE OF CONTENTS

INTRODUCTION

For several years upper atmospheric winds over the lower West Indies have been studied by firing high altitude ballistic probes from a sixteen-inch gun. The installation of a similar 16" gun at Yuma Proving Ground, New Mexico, early in 1966 has made possible a similar study of winds in this region. These firings are being carried out by the U. S. Army Ballistics Research Laboratories, Aberdeen Proving Ground, Maryland, under the direction of Dr. Charles H. Murphy, and by the Space Research Institute of McGill University, Canada, under the direction of Dr. G. V. Bull.

Atmospheric winds are studied by releasing chemical trails from the gun-fired probes during the upper portion of their trajectories. To date, the primary chemical which has been released is trimethyl aluminum (TMA). TMA produces a chemiluminescent glow in regions of the atmosphere above 85 kilometers, thus allowing the trails to be photographed while being distorted by upper atmosphere winds. The photographs are then reduced to provide wind information by Space Instruments Research, Inc. (SIR), using computer techniques.

The purpose of this report is to summarize results of these studies for the period from June 13 through June 15, 1966. Previous results for winds over Barbados, West Indies, are covered in Technical Reports Nos. 1, 2, and 3.

DATA ACQUISITION

The chemical trails are formed almost vertically over the gunsite (longitude 114.3°W, latitude 32.9°N) and extend from an altitude of approximately 85 kilometers through apogee. In some firings, TMA is also released on the down leg of the trajectory. To the unaided eye, the chemical release first appears as a straight white trail resembling a jet contrail. Within a minute or so, the trail is distorted into strange shapes by the upper atmospheric winds (see Figure 1) and fades from view within approximately fifteen minutes after initial release.

Space Instruments Research has established three photographic triangulation stations at Yuma and Gila Bend, Arizona, and Blythe, California. These sites are located at distances of up to 150 kilometers from the gunsite (see Figure 2).

Equipment at each site, built by SIR, consists of a camera unit containing two seven-inch focal length cameras mounted on a concrete pedestal, and an electronic control. Cameras are automatically pulsed to take exposures of 3, 6, and 12 seconds duration every 30 seconds.

Since commercial power is either unreliable or unavailable at many site locations, SIR has developed a battery operated 115-volt power supply for the control equipment. The power supply is tuning-fork controlled and provides 60 cycle power with an accuracy of 0.005% for the camera programmer so that pictures can be taken simultaneously at each site. A data block containing 24 tiny lights, mounted in each camera unit, records time, firing number, and site information in the corner of each frame of film.

During a typical night's operation, the gun is fired at one to two-hour intervals, from sunset to sunrise. Photographs are taken by all sites during the time that the trail is visible. The film is then returned to Atlanta for processing and data reduction.

DATA REDUCTION

Several computer programs have been developed which make it possible to calculate upper atmosphere winds from measurements made directly on the photographs of the luminous trails.

Since the method used is basically three-dimensional triangulation using spherical trigonometry, it is necessary to know precisely the direction each camera was pointed during a given firing. The direction is determined by first taking accurate measurements of the locations of several star images on the film, and then comouting the azimuth and elevation of the optical axis of the camera by means of a computer program. This computer program makes use of the celestial coordinates of some 6,000 stars which have been stored on magnetic tape.

Wind speeds and directions are then determined from the location of the trail in space at a succession of known times. The location is found, using either a point location program or a trail location program, or both, and depends on the physical shape of the chemical release cloud.

Point location method. If the chemical release exhibits discrete points (resulting either from turbulence or from the nature of the release mechanism) and these points can be identified on films from two or more sites, the point location program can be used to calculate the position of each point in longitude, latitude, and altitude above sea level.

These calculations mare made from data taken at successive times. A wind program is then used to calculate both vertical and horizontal winds from the motion of these points as a function of time.

Trail location method. Most of the chemical releases produce a smooth trail having few, if any, identifiable points. In such cases, film coordinates of a large number of incremental points along the film image of the trail are fed into the computer from data from two or more sites. The trail location program attempts to triangulate each point from one site with many points from another site, finally choosing points from both sites whose optical paths from camera into space form the closest spatial intersection. After doing many hundreds of such calculations, the computer is able to construct coordinates for a mathematical curve in the shape of the trail in space. Then, as with the point location program, winds can be determined from the motion of the curve with time. Here, however, it must be assumed that vertical winds are essentially zero. This assumption is borne out by previous studies which have shown vertical winds in this altitude region to be of the order of a few meters per second compared to horizontal winds ranging up to 150 meters per second.

Corrections for variables such as atmospheric refraction, rotation of camera about optical axis, and camera focal length, are incorporated into the programs to maintain high accuracy. Focal length and camera rotation are, in fact, calculated from measurements of the positions of star images on the films.

INTERPRETATION OF DATA

In the remainder of this report, horizontal wind velocities are presented in tabular form and in plots of wind speed, direction, and components.

Winds were calculated at altitude intervals of one kilometer. Points on the various plots show the actual computed result, as listed in the table preceding the plot. A curve has been fitted to each set of points to aid in detecting wind patterns and to indicate reliability of the plotted results. Each curve has been drawn with a knowledge of intermediate results leading to the wind calculations and of the consistency of the winds as calculated between each of the five or more time intervals used. In cases where point-to-point curve fitting was not thought to reflect actual variations in wind speed, direction, or components, a more appropriate smooth curve has been drawn. Otherwise, the curves are fitted directly to the data points. Results of certain portions of the trails are at times less accurate than others due to the spatial orientation of those trail segments relative to the available photographic stations. Less accurate data also can result from photographs obscured by haze and clouds and from trails of short duration.

Wind speed plot. This plot shows the speed of the wind in meters per second as a function of height in kilometers above sea level.

Wind direction plot. The wind vector is considered to point in the direction toward which the wind is moving. The direction plot shows the direction of this vector in degrees clockwise from north

as seen from above. Thus, a wind direction toward the east would be 90 degrees.

Wind components plot. While plots of wind direction and speed do completely describe the wind vector, it has been found helpful in studying wind patterns to present the north-south and east-west velocity components of the vector. In the north-south plot, north is positive; south is negative. In the east-west plot, east is positive, west negative. Components are plotted in meters per second versus height in kilometers.

The wind direction and components described above are referenced to true north. In addition, components have been calculated relative to magnetic north for comparison with other ionospheric phenomena. These components are not plotted but are listed in the tabulations preceding each set of plots.

Figure 1

Photographs of firing "McConnell"

Photographs taken 172 seconds after firing:

Yuma Blythe Gila Bend

These pictures were taken from three sites just as the vehicle reached apogee. Note that the winds have already distorted the trail. Numbers indicate altitude in kilometers.

Photographs taken 252 seconds after firing:

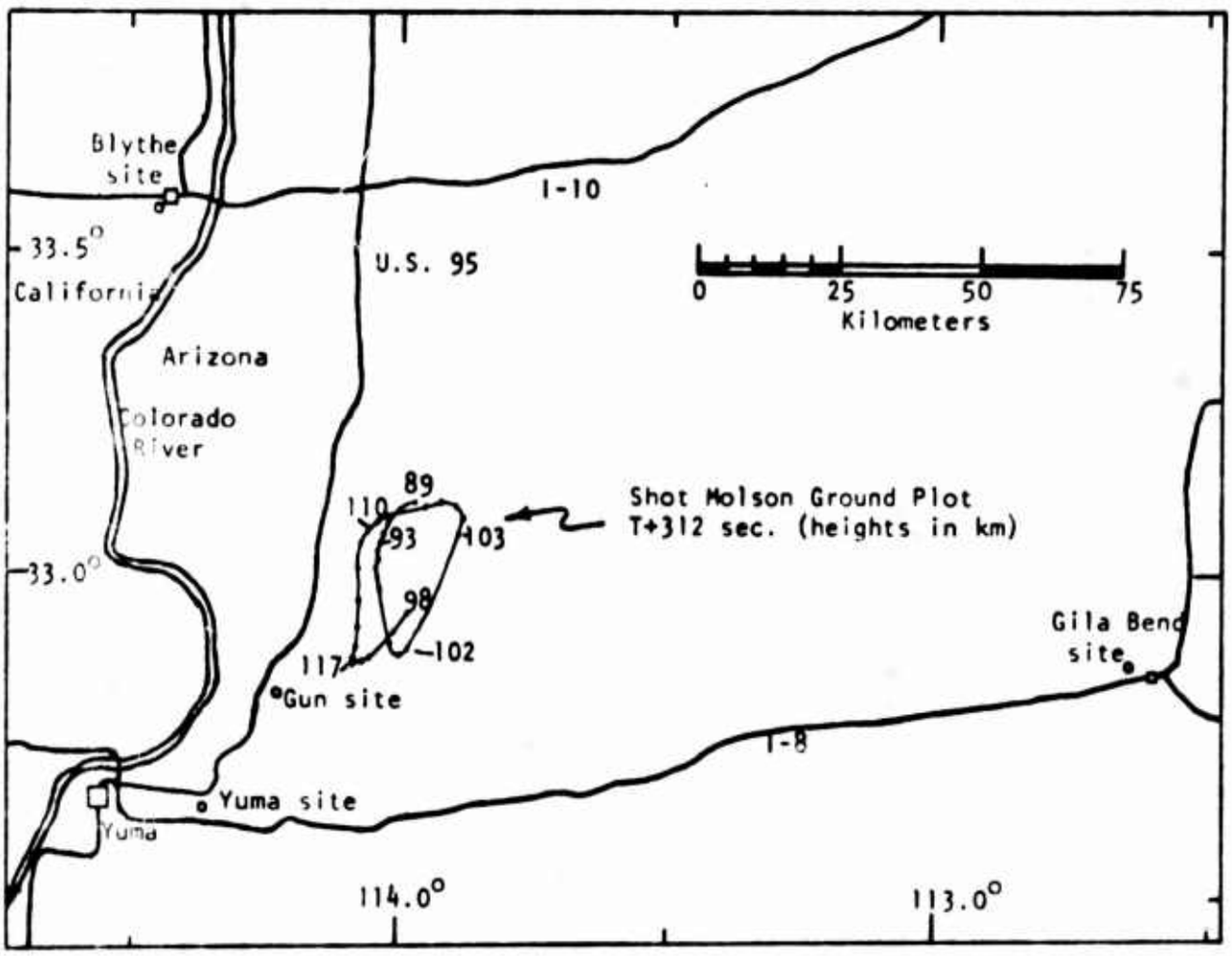
Yuma Blythe Gila Bend

This set of pictures was taken at completion of the downtrail. The uptrail shows the continued effect of the winds, while the lower part of the downtrail is new and only slightly distorted. Stars can be seen in the background of these pictures. The positions of these stars are used to determine the exact direction each camera was aimed.

Fig. 2

Location of SIR Photographic Stations

HARP - Yuma



SYNOPSIS OF RESULTS

The following comments may be helpful in interpreting the data contained in this report. Only those shots with unusual characteristics are discussed.

DAWSON

Shot Dawson had poor data below 95km. A dotted line has been drawn on the plots to show the general trend of the winds. At 95km and above, however, the results were quite accurate.

MCCONNELL

This was the only shot having good up and down trails. There was a distinct difference between up and down winds at many altitudes, but at other altitudes the possible errors in up and down trail results overlap. This was due to difficulty in identifying the trail because of its highly turbulent appearance. We have drawn two curves--through up and down winds. However, it is possible that at some altitudes there is no actual difference. At some altitudes there is also an indication that the uptrail winds shift at later times to agree with the downtrail at the time it was formed.

REFERENCES

1. Albritton, D. L., L. C. Young, H. D. Edwards, and J. L. Brown, "Position Determination of Artificial Clouds in the Upper Atmosphere," Photogrammetric Engineering, September 1962.

2. Armstrong, E. B., "Observations of Luminous Clouds Produced in the Upper Atmosphere by Exploding Grenades I, II and III," Planet, Space Sci., 11, 733-758, 1963.

3. Bedinger, J. F., Compendium of Wind Data from the Vapor Trail Technique," GCA Tech. Report. 66-7-N, March 1966.

4. Blamont, J. E., "Turbulence in Atmospheric Motions Between 90 and 130 km of Altitude," Planetary and Space Sciences, 10, 89-101, 1963.

5. Bull, G. V., C. H. Murphy, "Gun Launched Missiles for Upper Atmosphere Research," AIAA Preprint No. 64-18, January 1964.

6. Bull, G. V., H. J. Luckert, "Report of the March 1965 Test Firing Series," Project HARP, McGill University Report SRI-H-R-9, July 1965.

7. Cato, O., "Turbulent Diffusion of Sodium Vapor Trails in the Upper Atmosphere," GCA Technical Report No. 65-5-N, Contract NASw-1083, March 1965.

8. Champion, K. S. W., "Atmospheric Structure and Its Variations in the Lower Thermosphere," Planet, Space Sci., 13, 325-338, 1965.

9. Edwards, H. D., M. M. Cooksey, C. G. Justus, R. N. Fuller, D. L. Albritton, N. W. Rosenberg, "Upper Atmosphere Wind Measurements Determined from Twelve Rocket Experiments," J. Geophys. Res., 68, 3021-3032, 1963.

10. Edwards, H. D., C. G. Justus, D. C. Kurts, "Evening Twilight Winds from 68 to 140 Kilometers for May 21, 1963," J. Geophys. Res., 68, 6062-6063, 1963.

11. Elford, W. G., and R. G. Roper, "Turbulence in the Lower Thermosphere," to be published in Space Research VII, 1967.

12. Golomb, D., and M. M. MacLeod, "Diffusion Coefficients in the Upper Atmosphere from Chemiluminous Trails," J. Geophys. Res., 71, 2299-2305, 1966.

13. Golomb, D., N. W. Rosenberg, C. Abaronian, J. A. Hill, and H. L. Alden, "Oxygen Atom Determination in the Upper Atmosphere by Chemiluminescence of Vitric Oxide," J. Geophys. Res., 70, 1155-1173, 1965.

14. Hines, C. O., "Ionospheric Movements and Irregularities," Research in Geophysics, Vol. 1, 299-318, 1964.

15. Hines, C. O., "Minimum Vertical Scale Sizes in the Wird Structure Above 100 Kilometers," J. Geophys. Res., 69, 2847-2848, 1964.

16. Hines, C.O., "Dynamical Heating in the Upper Atmosphere," J. Geophys. Res., 70, 177-183, 1965.

17. Hines, C. O., "Diurnal Tide in the Upper Atmosphere," Jour. Geophys. Research 71, 1453, 1966.

18. Hines, C. O., "On the Analysis and Interpretation of Winds Observed at Heights of 85 to 135 Kilometers: A Rebuttal," J. Geophys. Res. 71, 1461, 1966.

19. Johnson, E. R., and R. H. Lloyd, "Determination of Diffusion Coefficients from Observations on Grenade Glow Clouds," Australian Jour. Phys. 16, 490-499, 1963.

20. Justus, C. G., "The Energy Balance of Turbulence in the Upper Atmosphere," J. Geophys. Res. 71, No. 15, August 1, 1966.

21. Justus, C. G., H. D. Edwards, R. N. Fuller, "A Method Employing Star Backgrounds for Improving the Accuracy of the Location of Clouds or Objects in Space," Photogrammetric Engineering, July 1964.

22. Kochanski, A., "Atmospheric Motions from Sodium Cloud Drifts at Four Locations," Monthly Weather Review, Vol. 94, No. 4, April 1966.

23. Lloyd, K. H., and L. M. Shappard, "Atmospheric Structure at 130-200 km Altitude from Observations on Grenade Glow Clouds During 1962-63," Australian Jour. Phys., 19, 323-342, 1966.

24. Morgan, A. W., "Measurements of Winds by Chemical Releases in the Upper Atmosphere, NASA Technical Memorandum, NASA TM X-53363, December 1965.

25. Murphy, C. H., G. V. Bull, H. D. Edwards, "Upper Atmosphere Winds Measured by Gun Launched Projectiles," AMS/AIAA Conference on Aerospace Meteorology, March 1966, and J. Geophys. Res. (in press).

26. Noel, T. M., "A Measurement of Turbulence Power and Small Eddy Scale Near 105 Kilometers," J. Geophys. Res., 68, 2862-2863, 1963.

27. Nordberg, W., "Rocket Soundings in the Mesosphere," in NASA SP-49 (Meteorological Observations above 30 km) 1964.

28. Roper, R. G., "Dissipation of Wind Energy in the Height Range 80 to 140 km," Jour. Geophys. Res., 71, September 15, 1966.

29. Roper, R. G., "The Semidiurnal Tide in the Lower Thermosphere," Jour. Geophys. Res. (accepted for publication, probably Dec. 15, 1966).

30. Roper, R. G., "Atmospheric Turbulence in the Meteor Region," Jour. Geophys. Res. (accepted for publication, probably December 15, 1966.)

31. Rosenberg, N. W., H. D. Edwards, and J. W. Wright, "Ionospheric Winds: Motions into Night and Sporadic E Correlations," Space Research 4, 171-181, 1964.

32. Rosenberg, N. W., D. Golomb, E. F. Allen, "Chemiluminescence of Trimethyl aluminum Released into the Upper Atmosphere," J. Geophys. Res. 68, 5895-5898, 1963.

33. Rosenberg, N. W., D. Golomb, E. F. Allen, "Resonance Radiation of AlO from Trimethyl Aluminum Released into the Upper Atmosphere," J. Geophys. Res. 69, 1451-1454, 1964.

34. Rosenberg, N. W., D. Golomb, E. F. Allen, "Chemiluminescent Techniques for Studying Nighttime Winds in the Upper Atmosphere," J. Geophys. Res. 68, 3328-3330, 1963.

35. Rosenberg, N. W., C. G. Justus, "Space and Time Correlations of Ionospheric Winds," Radio Science, 1, No. 2, February 1966.

36. Shappard, L. M., and K. H. Lloyd, "Atmospheric Density and the Diffusion of Grenade Glow Clouds," Planet Space Sci., 12, 317-318, 1964.

37. Zimmerman, "Small-Scale Wind Structure Above 100 km," Jour. Geophys. Res., 69, 784-785, 1964.

TABLE OF TRAIL INFORMATION

Trail No.	Name	Date	Time(MST)	Altitudes (km)
Y1	Beatty	13 June 1966	20:25:00	94-125
Y2	Dawson	13 June 1966	22:15:01	92-121
Y3	Douglas	14 June 1966	21:46:01	91-120
Y4	McConnell	15 June 1966	01:27:00	85-115
Y5	Molson	15 June 1966	03:05:01	87-122

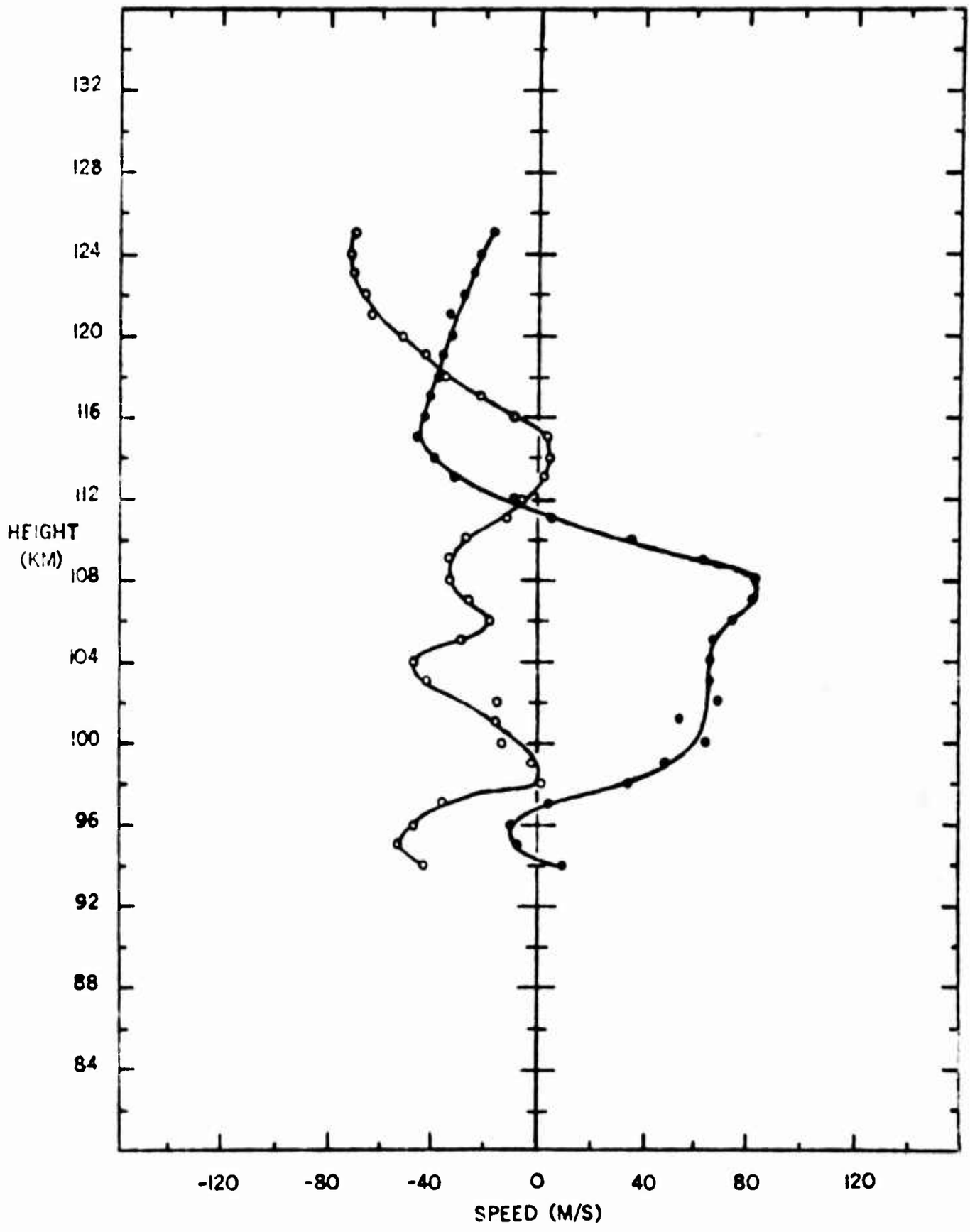
TABULATIONS AND PLOTS

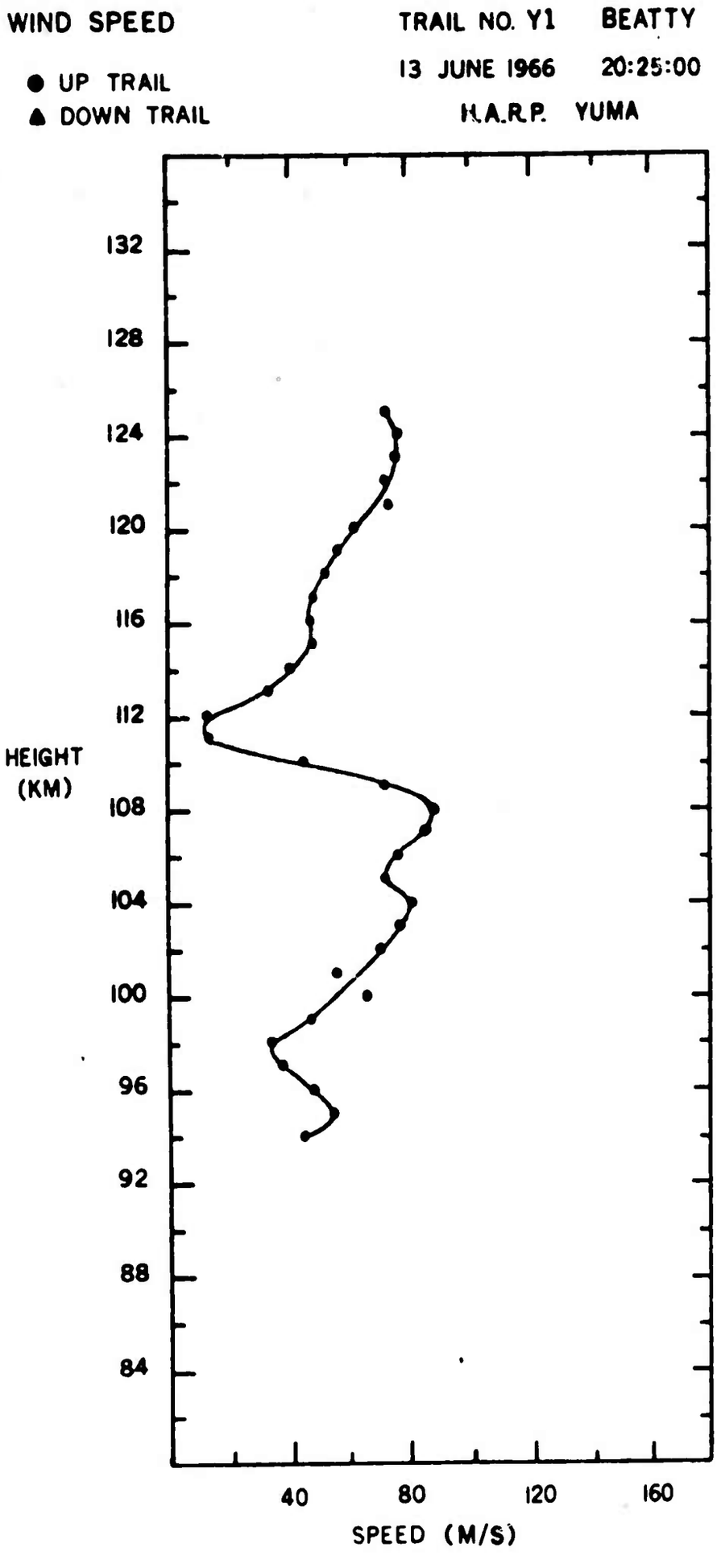
Five Trail Releases - June 13-15, 1966

TRAIL NO. Y1 BEATTY

YUMA 13 JUNE 1966 20-24-60 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
94.0	167.3	44.6	-43.5	9.8	-39.7	20.2
95.0	188.3	54.9	-54.3	-7.9	-54.6	5.7
96.0	192.2	47.9	-46.8	-10.1	-47.8	1.7
97.0	174.5	36.7	-36.6	3.5	-34.6	12.4
98.0	89.2	34.8	0.5	34.8	9.1	33.6
99.0	92.5	46.5	-2.1	46.5	9.4	45.6
100.0	102.4	65.7	-14.1	64.2	2.1	65.7
101.0	106.3	57.4	-16.1	55.1	-2.0	57.4
102.0	102.4	71.7	-15.4	70.0	2.3	71.6
103.0	122.8	77.6	-42.0	65.3	-24.6	73.6
104.0	126.4	80.9	-48.0	65.1	-30.5	74.9
105.0	113.9	72.3	-29.2	66.1	-12.0	71.3
106.0	104.3	76.0	-18.7	73.6	0.0	75.9
107.0	107.9	85.2	-26.2	81.0	-5.5	85.0
108.0	112.1	88.0	-33.1	81.5	-12.0	87.1
109.0	118.2	71.7	-33.9	63.2	-17.3	69.6
110.0	128.3	44.2	-27.4	34.7	-18.0	40.4
111.0	159.4	12.9	-12.1	4.5	-10.6	7.3
112.0	234.5	11.5	-6.7	-9.4	-8.8	-7.5
113.0	272.3	31.9	1.3	-31.8	-6.6	-31.1
114.0	276.6	39.5	4.5	-39.2	-5.3	-39.1
115.0	273.3	46.7	2.7	-46.6	-8.9	-45.8
116.0	257.8	45.4	-9.6	-44.4	-20.2	-40.7
117.0	242.7	47.2	-21.7	-41.9	-31.3	-35.3
118.0	226.9	51.0	-34.9	-37.2	-43.0	-27.5
119.0	220.4	55.8	-42.5	-36.1	-50.1	-24.5
120.0	212.4	61.5	-51.9	-32.9	-58.4	-19.1
121.0	207.7	73.0	-64.6	-33.9	-71.0	-17.0
122.0	203.2	72.4	-66.6	-28.5	-71.6	-11.2
123.0	199.3	75.2	-71.0	-24.8	-74.9	-6.6
124.0	196.5	75.8	-72.7	-21.5	-75.8	-2.9
125.0	193.6	72.7	-70.7	-17.1	-72.7	0.8


WIND COMPONENTS
TRAIL NO. Y1 BEATTY
UP DOWN
13 JUNE 1966 20:25:00
NORTH- SOUTH
EAST-WEST
H.A.R.P. YUMA
132
128
124
120
116
112
HEIGHT (KM)
108
104
100
96
92
88
84
-120
-80
-40
0
40
80
120
SPEED (M/S)


WIND SPEED
TRAIL NO. Y1 BEATTY
13 JUNE 1966 20:25:00
H.A.R.P. YUMA
● UP TRAIL
▲ DOWN TRAIL
HEIGHT (KM)
132
128
124
120
116
112
108
104
100
96
92
88
84
40
80
120
160
SPEED (M/S)

WIND DIRECTION

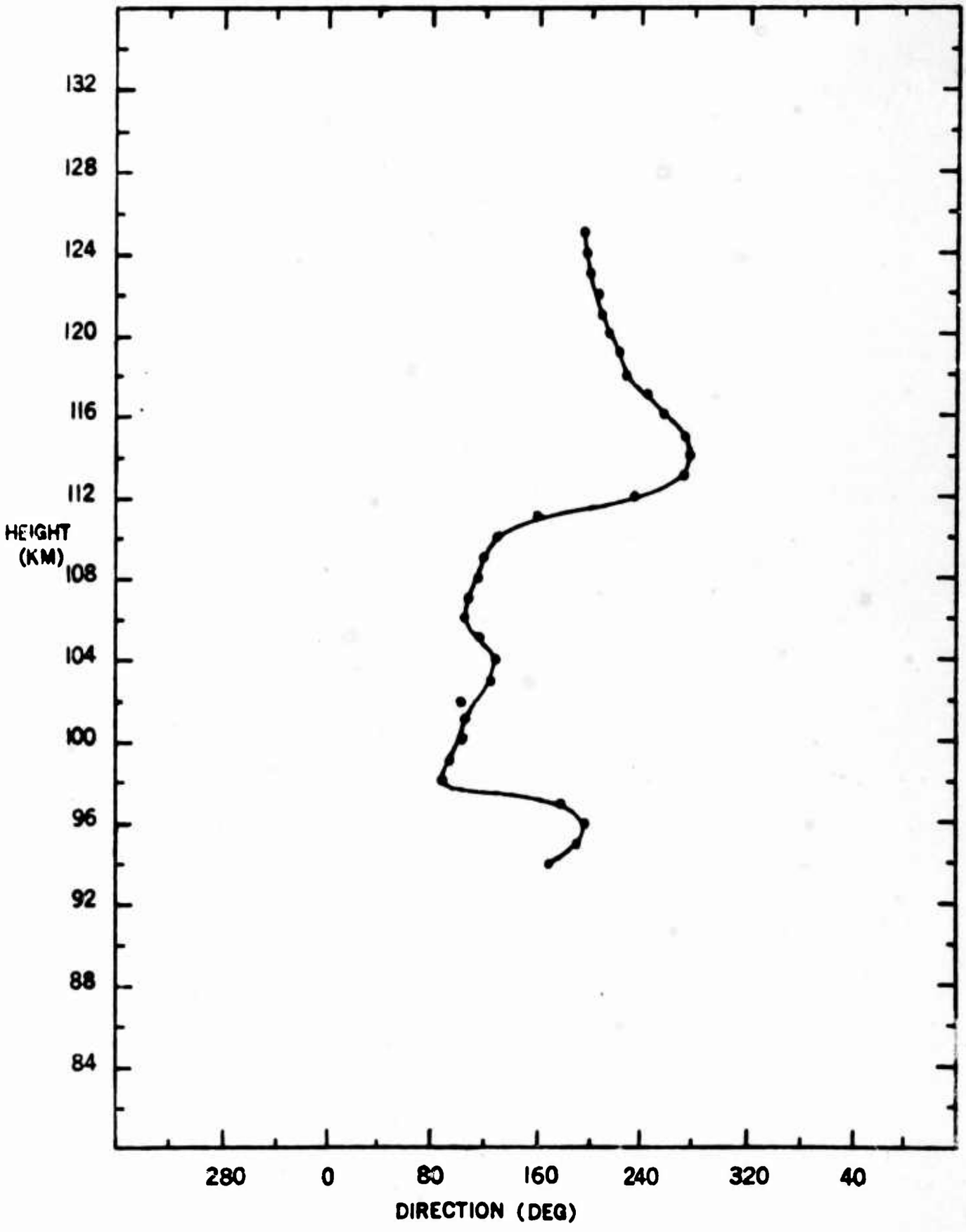
● UP TRAIL

▲ DOWN TRAIL

TRAIL NO. Y1 BEATTY

13 JUNE 1966 20:25:00

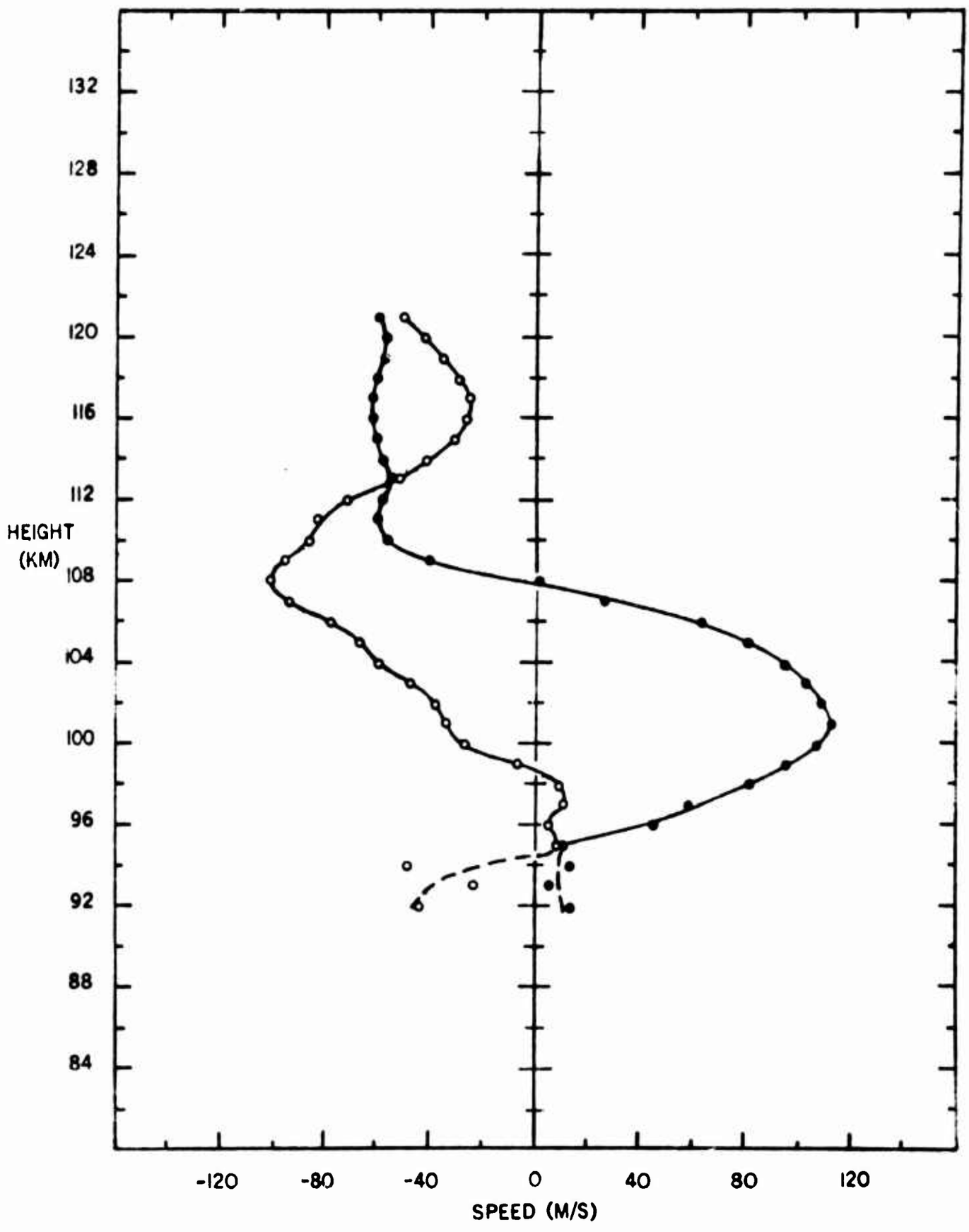
H.A.R.P. YUMA



TRAIL NO. Y2 DAWSON

YUMA 13 JUNE 1966 22-15-01 MST

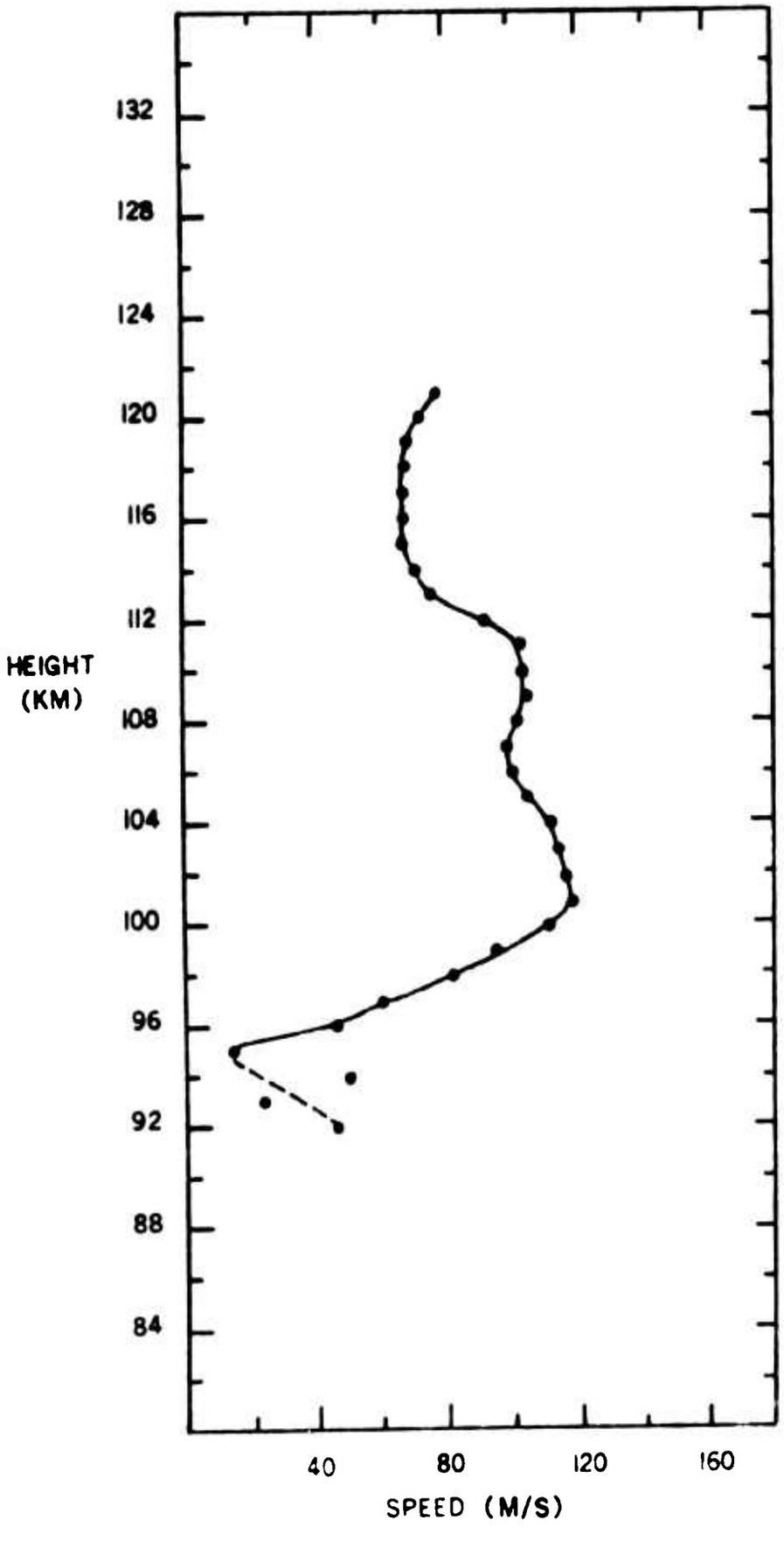
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
92.0	163.2	45.5	-43.5	13.1	-38.9	23.4
93.0	167.3	23.1	-22.6	5.1	-20.6	10.5
94.0	164.5	50.1	-48.2	13.4	-43.4	24.9
95.0	52.8	13.7	8.3	10.9	10.7	8.5
96.0	83.7	45.6	5.0	45.3	16.0	42.7
97.0	80.0	60.2	10.5	59.3	24.8	54.9
98.0	84.1	82.1	8.5	81.7	28.3	77.1
99.0	93.8	95.3	-6.4	95.1	17.2	93.7
100.0	103.6	110.7	-26.1	107.6	1.2	110.7
101.0	106.6	117.9	-33.6	113.0	-4.8	117.8
102.0	109.4	116.2	-38.7	109.6	-10.5	115.8
103.0	115.1	113.6	-48.1	102.9	-21.3	111.6
104.0	122.1	111.9	-59.4	94.8	-34.2	106.5
105.0	129.8	104.7	-67.0	80.4	-45.1	94.4
106.0	141.2	100.5	-78.3	63.0	-60.4	80.3
107.0	164.4	98.2	-94.6	26.4	-85.2	48.9
108.0	179.3	102.3	-102.2	1.3	-98.7	26.4
109.0	202.5	104.6	-96.6	-40.0	-103.5	-15.0
110.0	213.0	103.2	-86.5	-56.2	-97.7	-33.2
111.0	215.7	103.6	-84.2	-60.4	-96.5	-37.8
112.0	218.6	92.3	-72.2	-57.6	-84.2	-38.1
113.0	226.4	75.7	-52.2	-54.8	-64.1	-40.3
114.0	234.5	70.8	-41.1	-57.6	-54.0	-45.7
115.0	243.5	67.2	-30.0	-60.1	-43.9	-50.9
116.0	247.1	67.0	-26.1	-61.7	-40.5	-53.4
117.0	247.9	66.9	-25.1	-62.0	-39.6	-53.9
118.0	244.2	67.1	-29.2	-60.4	-43.2	-51.4
119.0	238.8	67.7	-35.1	-57.9	-48.3	-47.5
120.0	233.8	71.2	-42.0	-57.4	-54.8	-45.3
121.0	229.9	77.7	-50.1	-59.5	-63.2	-45.3


WIND COMPONENTS
TRAIL NO. Y2
DAWSON
UP DOWN
13 JUNE 1966
22:15:01
NORTH- SOUTH
EAST-WEST
HARP. YUMA
132
128
124
120
116
112
HEIGHT
(KM)
108
104
100
96
92
88
84
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

● UP TRAIL
▲ DOWN TRAIL

TRAIL NO. Y2 DAWSON
13 JUNE 1966 22:15:01
H.A.R.P. YUMA



WIND DIRECTION

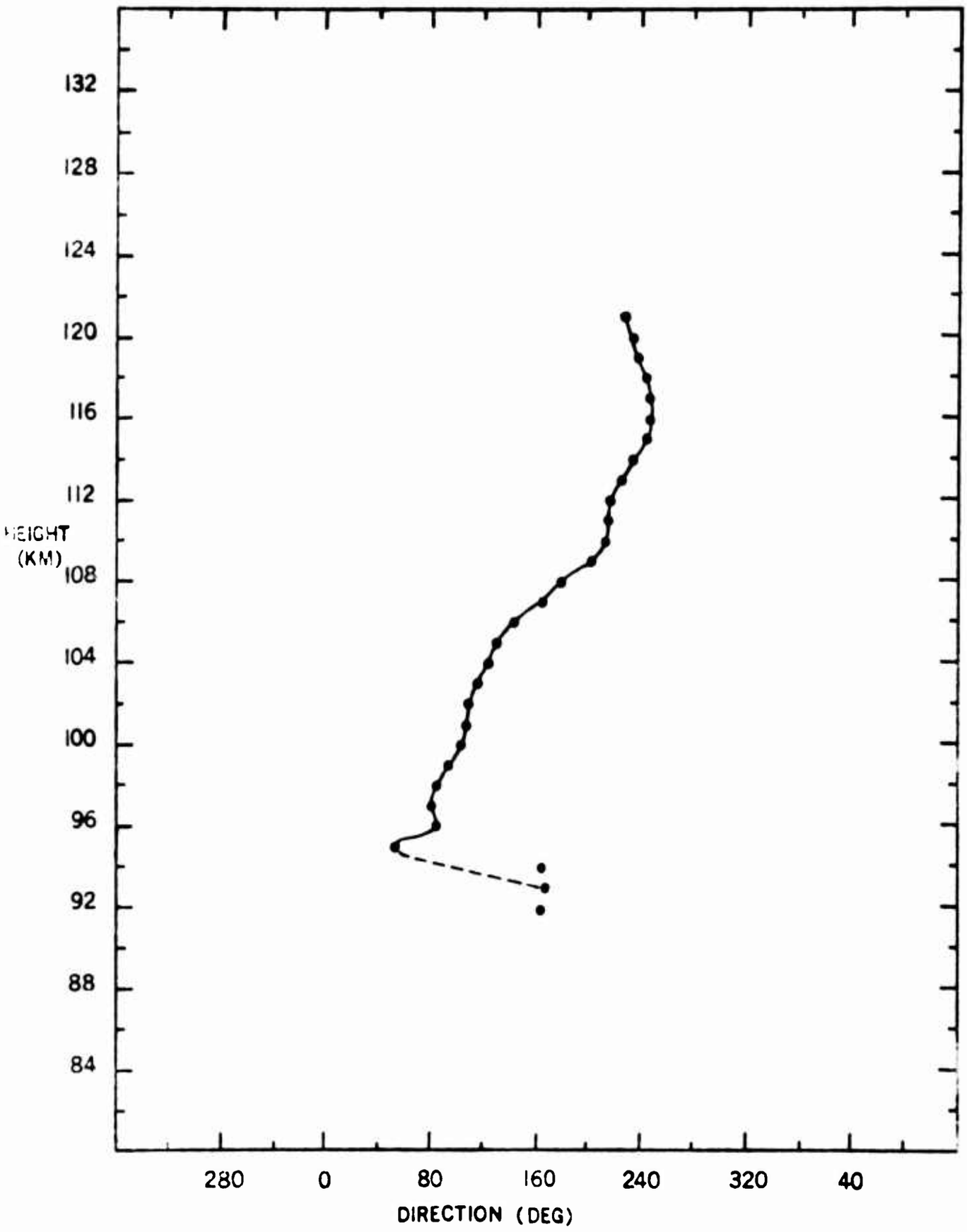
● UP TRAIL

▲ DOWN TRAIL

TRAIL NO. Y2 DAWSON

13 JUNE 1966 22:15:01

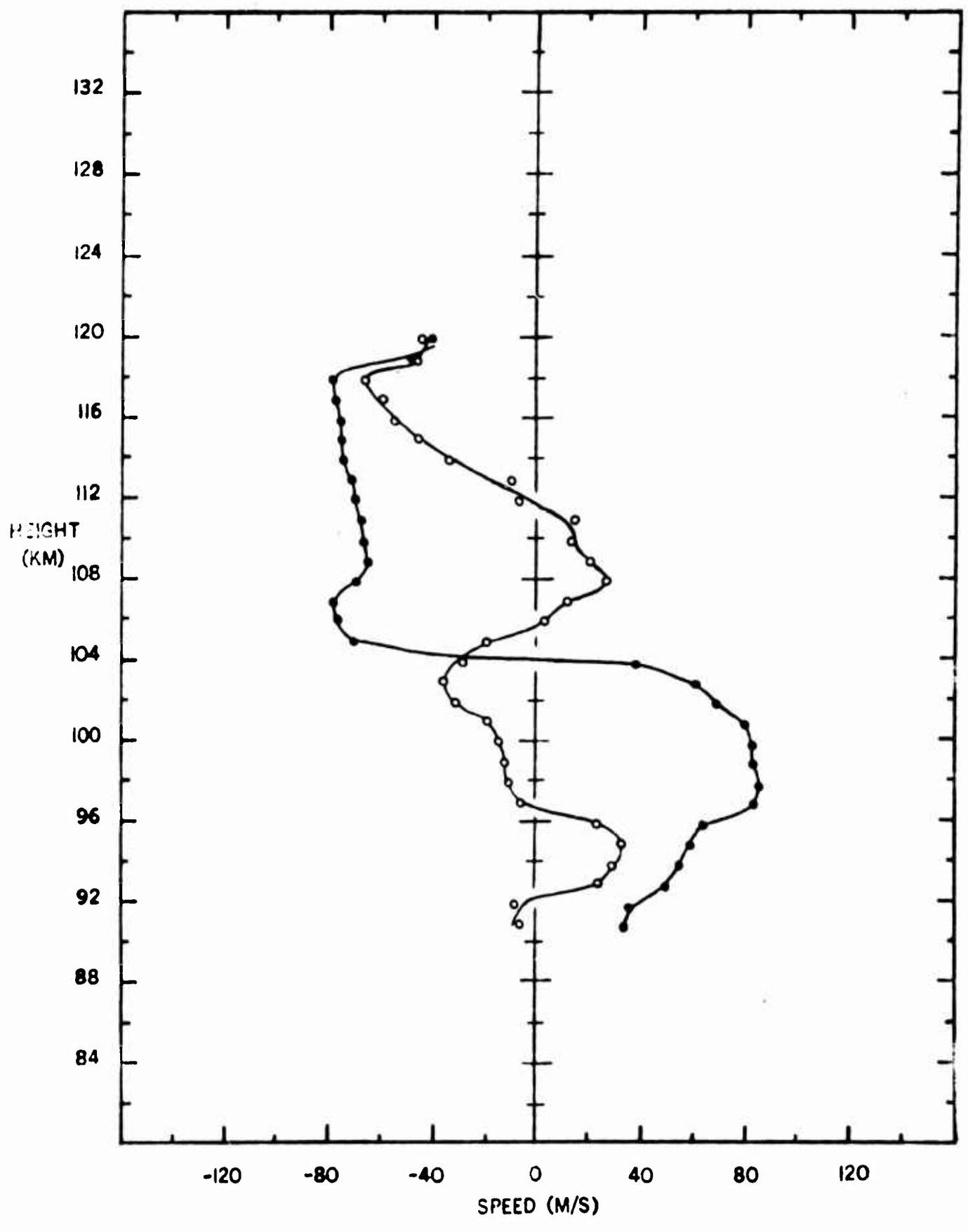
H.A.R.P. YUMA

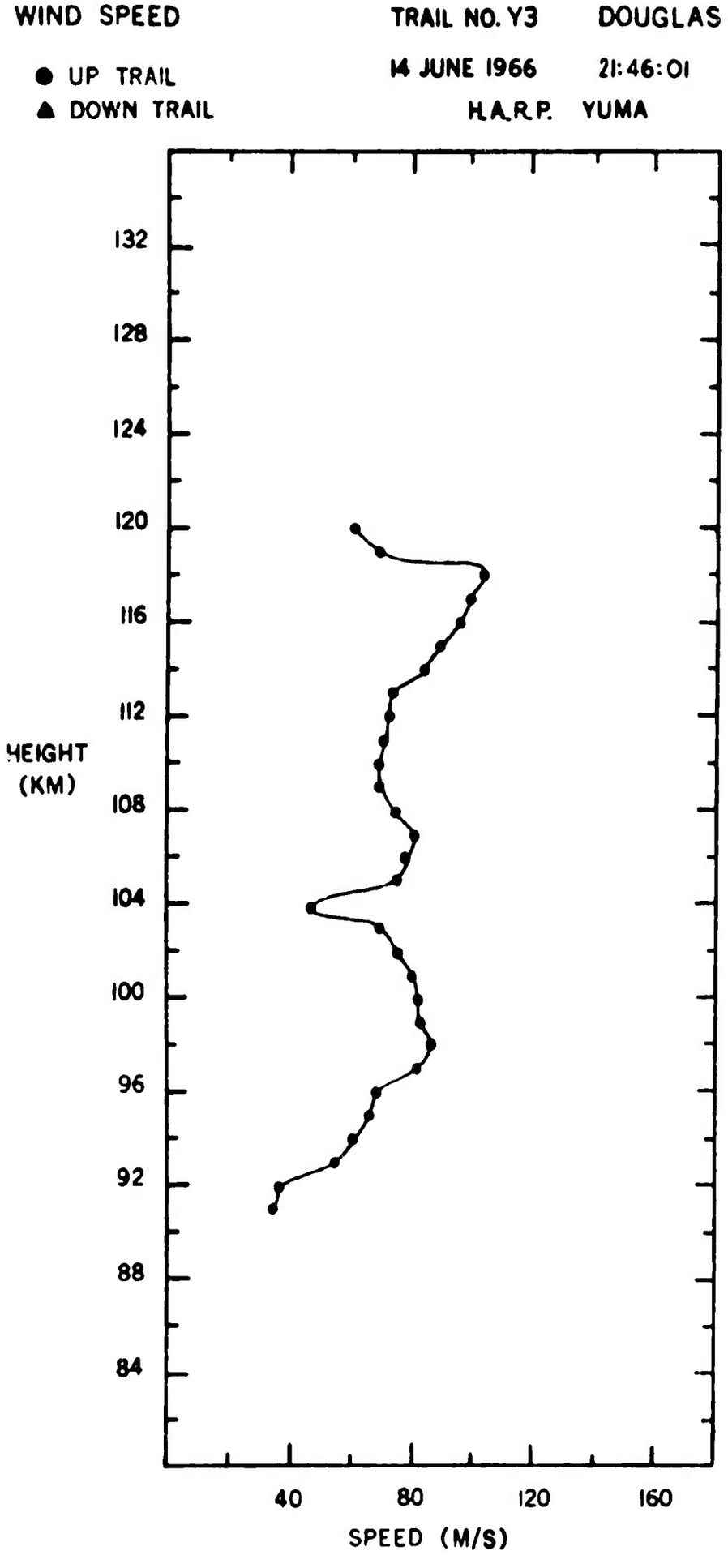


TRAIL NO. Y3 DOUGLAS

YUMA 14 JUNE 1966 21-46-01 MST

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
91.0	100.8	34.4	-6.5	33.8	2.0	34.4
92.0	104.5	35.3	-8.8	34.2	-0.1	35.3
93.0	64.3	54.9	23.8	49.5	35.3	42.1
94.0	62.6	61.3	28.2	54.4	40.7	45.8
95.0	62.0	66.1	31.0	58.4	44.4	49.0
96.0	70.3	67.8	22.9	63.8	37.9	56.2
97.0	94.7	81.6	-6.7	81.4	13.5	80.5
98.0	97.9	85.1	-11.8	84.3	9.3	84.6
99.0	99.6	82.7	-13.8	81.6	6.7	82.5
100.0	101.4	82.2	-16.2	80.6	4.1	82.1
101.0	104.5	80.5	-20.2	78.0	-0.4	80.6
102.0	115.7	75.0	-32.6	67.5	-15.0	73.4
103.0	122.0	69.8	-37.0	59.2	-21.3	66.5
104.0	130.4	46.9	-30.4	35.7	-20.7	42.1
105.0	253.5	75.0	-21.4	-71.8	-38.4	-64.3
106.0	271.2	77.4	1.6	-77.4	-17.5	-75.4
107.0	277.2	80.4	10.1	-79.8	-9.9	-79.8
108.0	289.3	74.7	24.6	-70.5	6.5	-74.4
109.0	285.4	69.3	18.4	-66.8	1.4	-69.3
110.0	280.0	68.8	11.9	-67.8	-5.2	-68.6
111.0	280.8	69.5	13.0	-68.3	-4.2	-69.4
112.0	263.1	71.1	-8.6	-70.6	-25.7	-66.3
113.0	261.0	73.2	-11.5	-72.3	-28.9	-67.2
114.0	245.0	83.3	-35.2	-75.5	-52.7	-64.5
115.0	238.3	89.8	-47.1	-76.4	-64.5	-62.5
116.0	234.1	95.3	-55.9	-77.1	-73.2	-61.0
117.0	232.5	99.5	-60.5	-79.0	-78.1	-61.7
118.0	229.7	104.8	-67.8	-79.9	-85.4	-60.8
119.0	225.8	67.9	-47.4	-48.7	-57.9	-35.5
120.0	223.3	60.5	-44.0	-41.5	-52.9	-29.4


WIND COMPONENTS
TRAIL NO. Y3
DOUGLAS
UP DOWN
14 JUNE 1966
21:46:01
NORTH- SOUTH
EAST-WEST
H.A.R.P. YUMA
132
128
124
120
116
112
HEIGHT
(KM)
108
104
100
96
92
88
84
-120
-80
-40
0
40
80
120
SPEED (M/S)


WIND SPEED
TRAIL NO. Y3
DOUGLAS
● UP TRAIL
▲ DOWN TRAIL
14 JUNE 1966
21:46:01
H.A.R.P. YUMA
132
128
124
120
116
112
HEIGHT (KM)
108
104
100
96
92
88
84
40
80
120
160
SPEED (M/S)

WIND DIRECTION

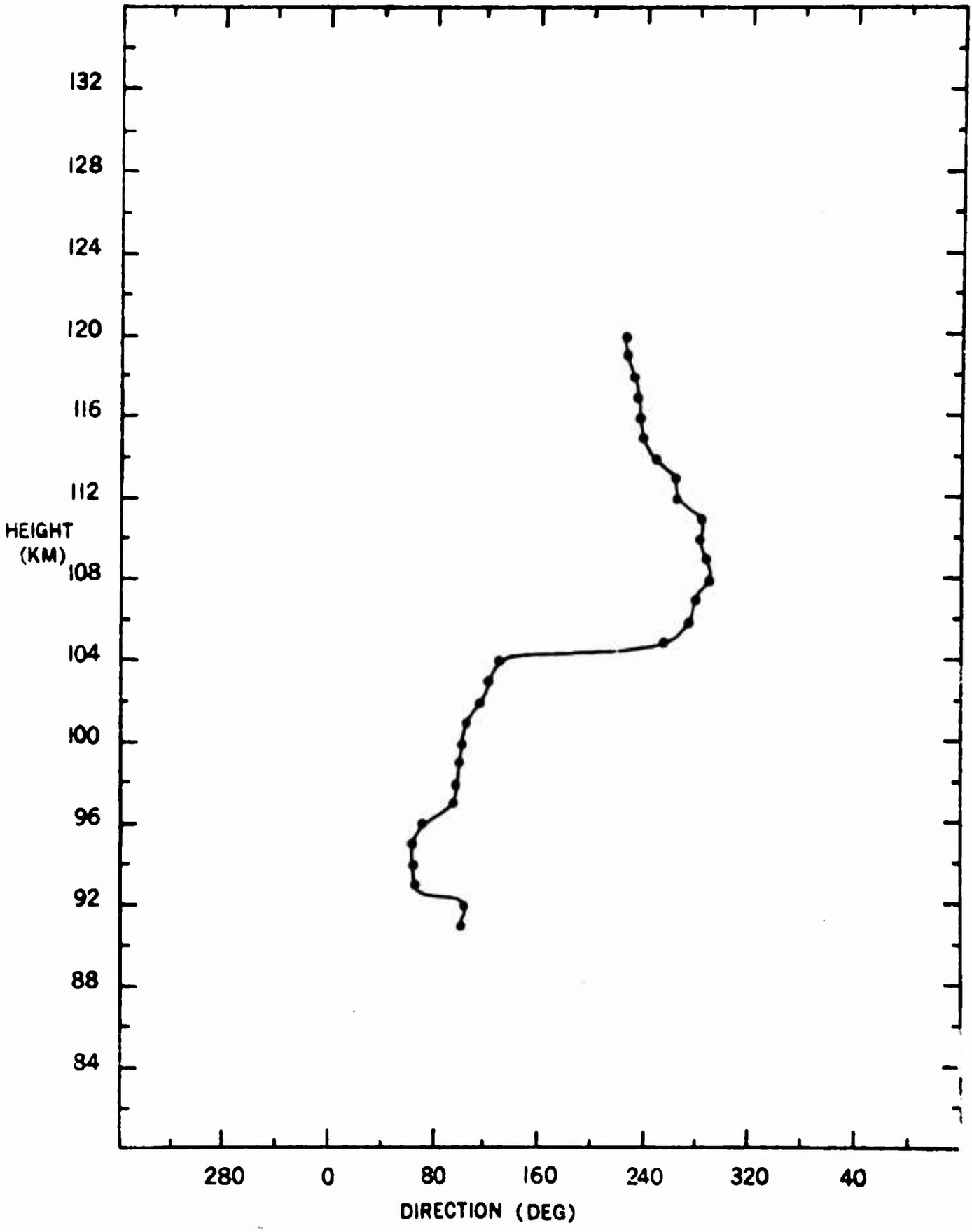
● UP TRAIL

▲ DOWN TRAIL

TRAIL NO. Y3 DOUGLAS

14 JUNE 1966 21:46:01

H.A.R.P. YUMA



TRAIL NO. Y4 MCCONNELL

YUMA 15 JUNE 1966 01-27 00 MST

UP TRAIL

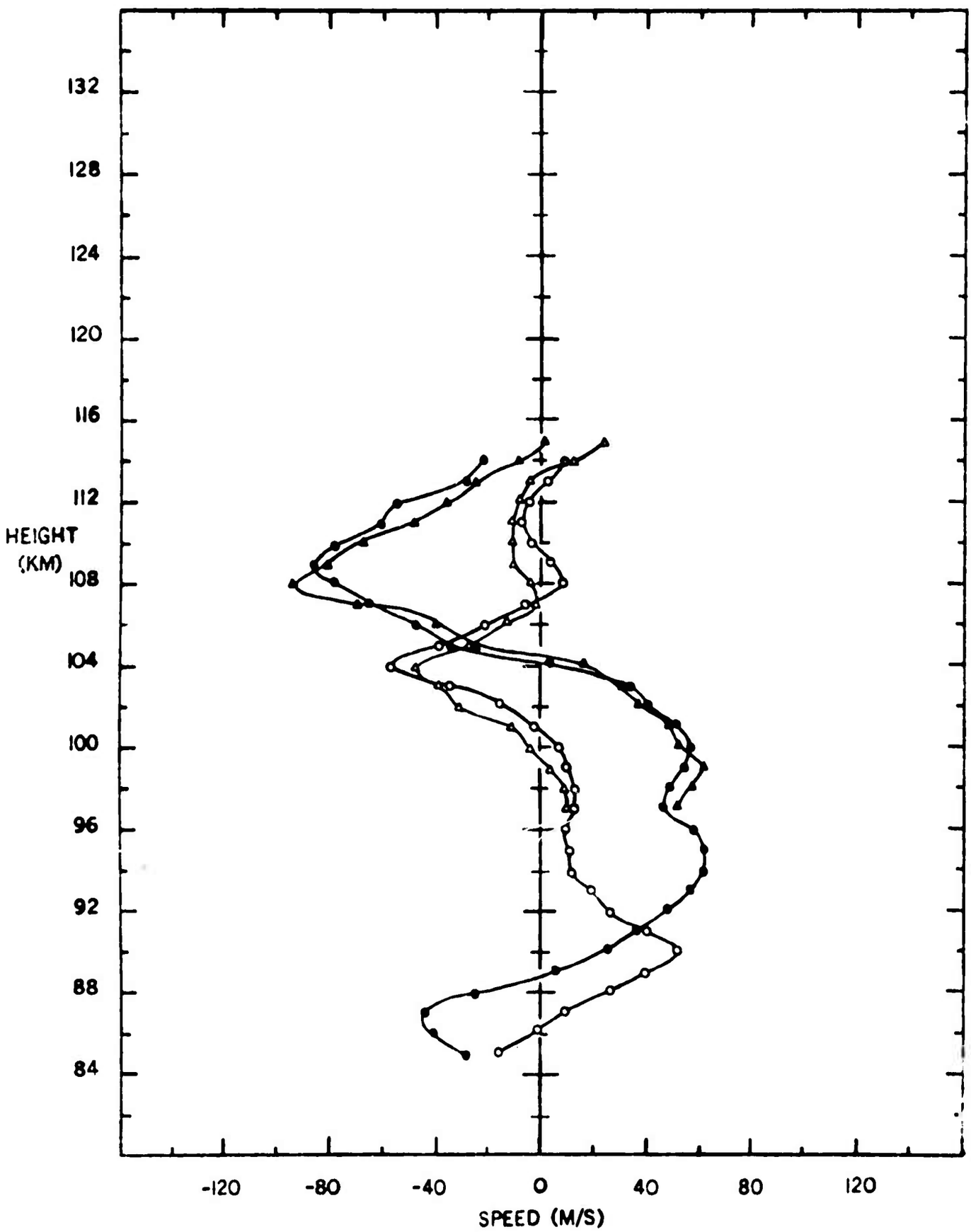
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
85.0	242.4	32.9	-15.2	-29.1	-21.9	-24.5
86.0	267.0	42.5	-2.2	-42.4	-12.6	-40.6
87.0	281.1	47.5	9.1	-46.6	-2.7	-47.4
88.0	314.0	36.9	25.6	-26.6	18.3	-32.1
89.0	9.6	39.9	39.3	6.6	39.7	-3.3
90.0	24.8	58.0	52.6	24.3	57.0	10.6
91.0	43.5	53.1	38.6	36.6	46.4	26.0
92.0	61.7	53.9	25.5	47.5	36.4	39.8
93.0	72.4	59.5	18.0	56.7	31.4	50.5
94.0	77.5	62.7	13.5	61.2	28.1	56.0
95.0	80.1	62.9	10.8	61.9	25.7	57.3
96.0	80.4	57.9	9.6	57.1	23.4	53.0
97.0	75.0	48.0	12.4	46.3	23.4	41.8
98.0	75.5	49.6	12.4	48.0	23.8	43.5
99.0	78.7	53.9	10.6	52.8	23.3	48.6
100.0	82.9	57.0	7.1	56.5	20.8	53.0
101.0	93.0	50.2	-2.6	50.1	9.8	49.2
102.0	110.5	43.0	-15.1	40.2	-4.7	42.7
103.0	136.2	48.8	-35.3	33.8	-25.9	41.4
104.0	176.5	57.7	-57.6	3.6	-54.9	17.7
105.0	221.8	53.1	-39.6	-35.4	-47.1	-24.6
106.0	245.5	52.9	-21.9	-48.1	-33.1	-41.2
107.0	265.5	66.3	-5.2	-66.1	-21.3	-62.8
108.0	275.1	79.8	7.1	-79.5	-12.7	-78.8
109.0	272.3	87.4	3.5	-87.3	-18.1	-85.5
110.0	267.1	78.6	-4.0	-78.5	-23.2	-75.1
111.0	263.7	62.5	-6.8	-62.1	-21.9	-58.5
112.0	266.5	55.5	-3.4	-55.4	-16.9	-52.9
113.0	276.1	28.6	3.0	-28.4	-4.1	-28.3
114.0	291.3	25.5	9.3	-23.8	3.2	-25.4

TRAIL NO. Y4 M CONNELL

YUMA 15 JUNE 1966 01-27 00 MST

DOWN TRAIL

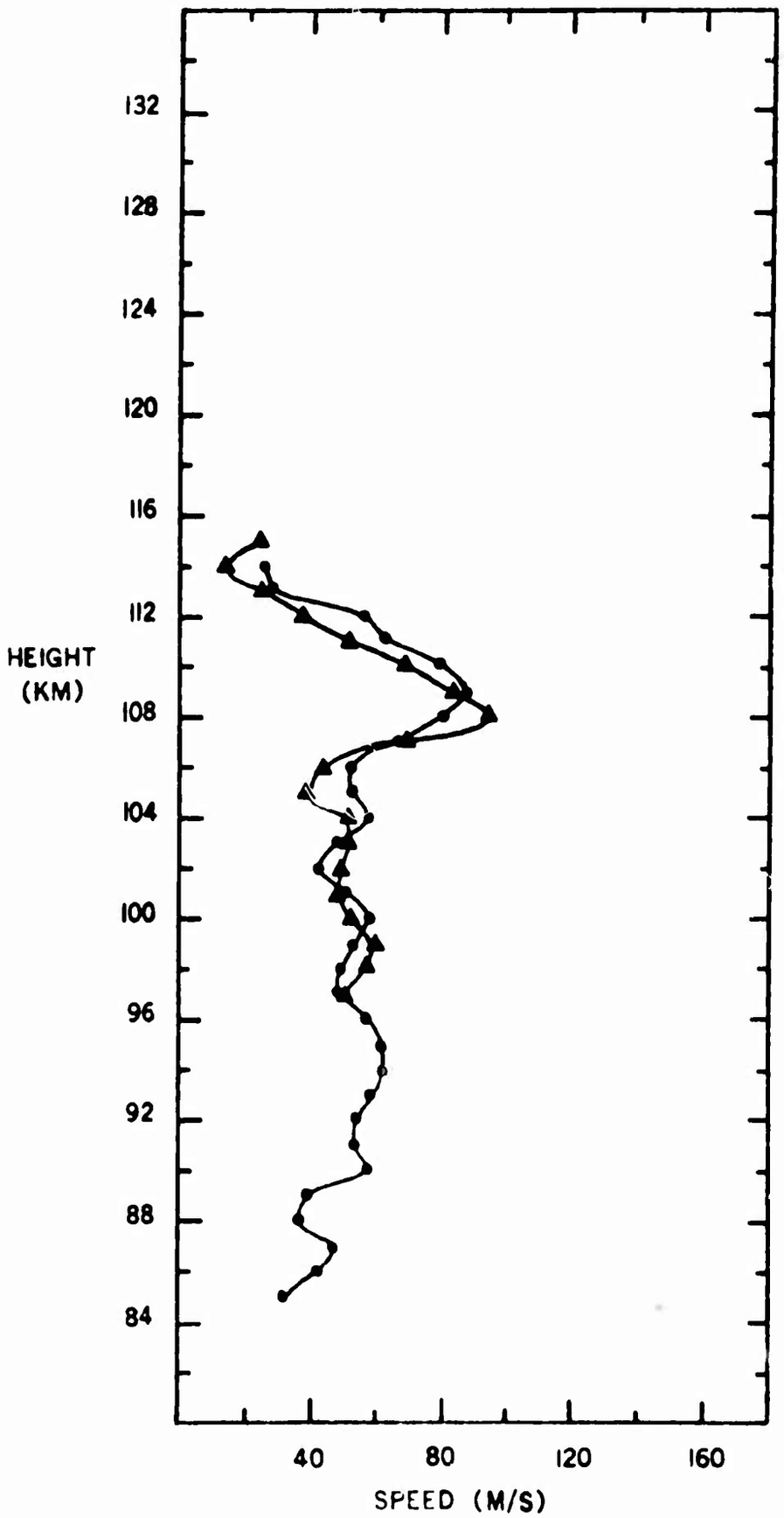
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
97.0	76.4	52.2	12.3	50.8	24.4	46.2
98.0	79.0	57.5	11.0	56.5	24.6	52.1
99.0	87.1	60.4	3.1	60.3	17.8	57.7
100.0	95.3	53.6	-4.9	53.4	8.4	53.0
101.0	102.7	50.5	-11.1	49.2	1.4	50.4
102.0	128.8	49.8	-31.2	38.8	-20.7	45.3
103.0	139.9	52.2	-39.9	33.7	-30.4	42.5
104.0	161.6	52.4	-49.7	16.6	-44.1	28.3
105.0	221.7	38.6	-28.8	-25.7	-34.2	-17.8
106.0	251.6	43.5	-13.7	-41.2	-23.4	-36.6
107.0	268.6	69.4	-1.8	-69.3	-18.8	-66.7
108.0	267.7	94.9	-3.8	-94.8	-27.0	-90.9
109.0	262.8	83.1	-10.4	-82.4	-30.4	-77.3
110.0	259.5	69.1	-12.5	-67.9	-28.8	-62.7
111.0	257.0	50.9	-11.5	-49.6	-23.4	-45.2
112.0	256.7	37.7	-8.7	-36.7	-17.5	-33.4
113.0	260.1	25.8	-4.4	-25.4	-10.5	-23.5
114.0	325.8	14.6	12.0	-8.2	9.6	-10.9
115.0	6.8	24.5	24.4	2.9	24.4	-3.2


WIND COMPONENTS
TRAIL NO. Y4
McCONNELL
UP DOWN
15 JUNE 1966
01:27:00
NORTH- SOUTH
EAST-WEST
HARP. YUMA
132
128
124
120
116
112
HEIGHT (KM)
108
104
100
96
92
88
84
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

● UP TRAIL
▲ DOWN TRAIL

TRAIL NO. Y4 McCONNELL
15 JUNE 1966 01:27:00
H.A.R.P. YUMA



WIND DIRECTION

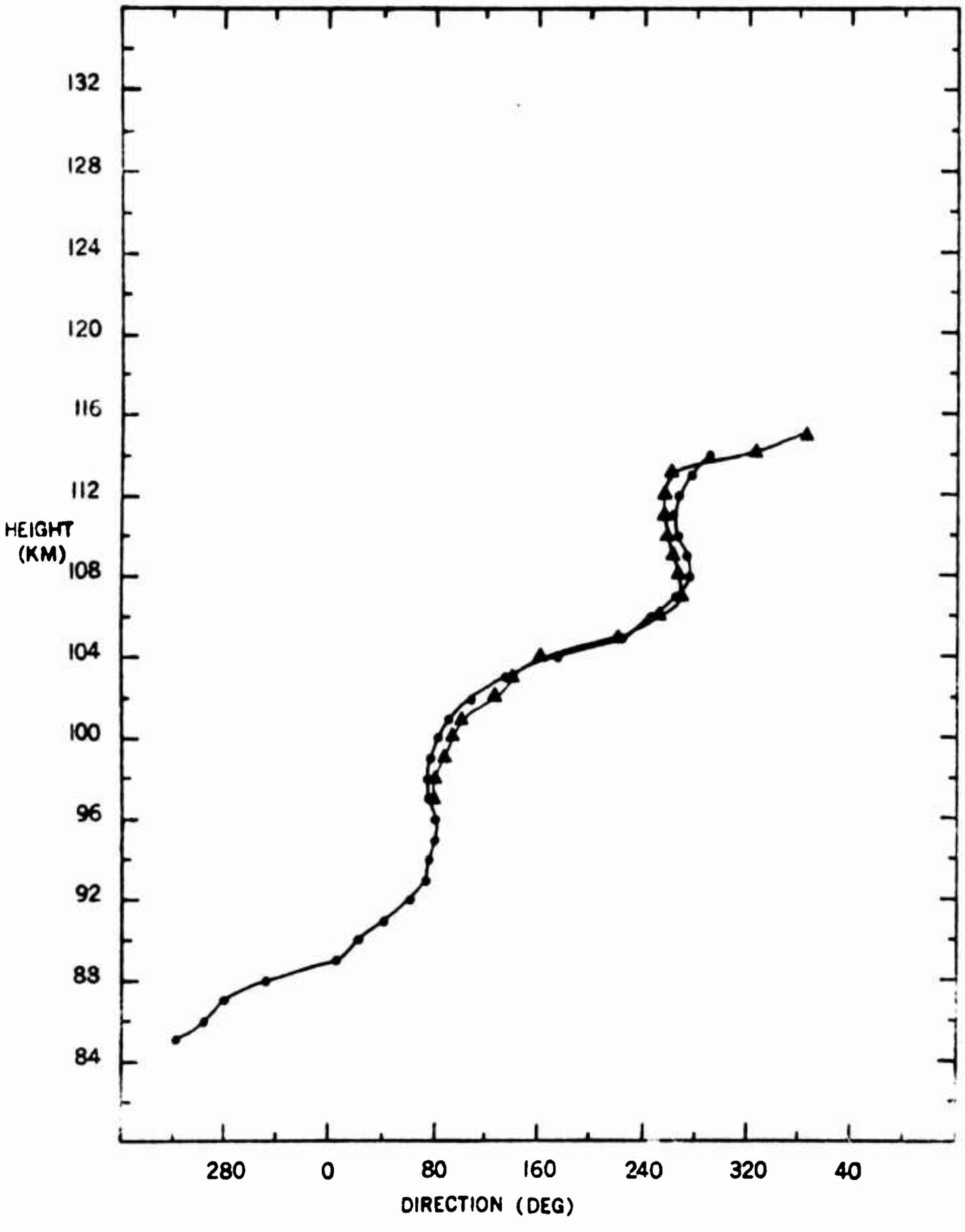
● UP TRAIL

▲ DOWN TRAIL

TRAIL NO. Y4 McCONNELL

15 JUNE 1966 01:27:00

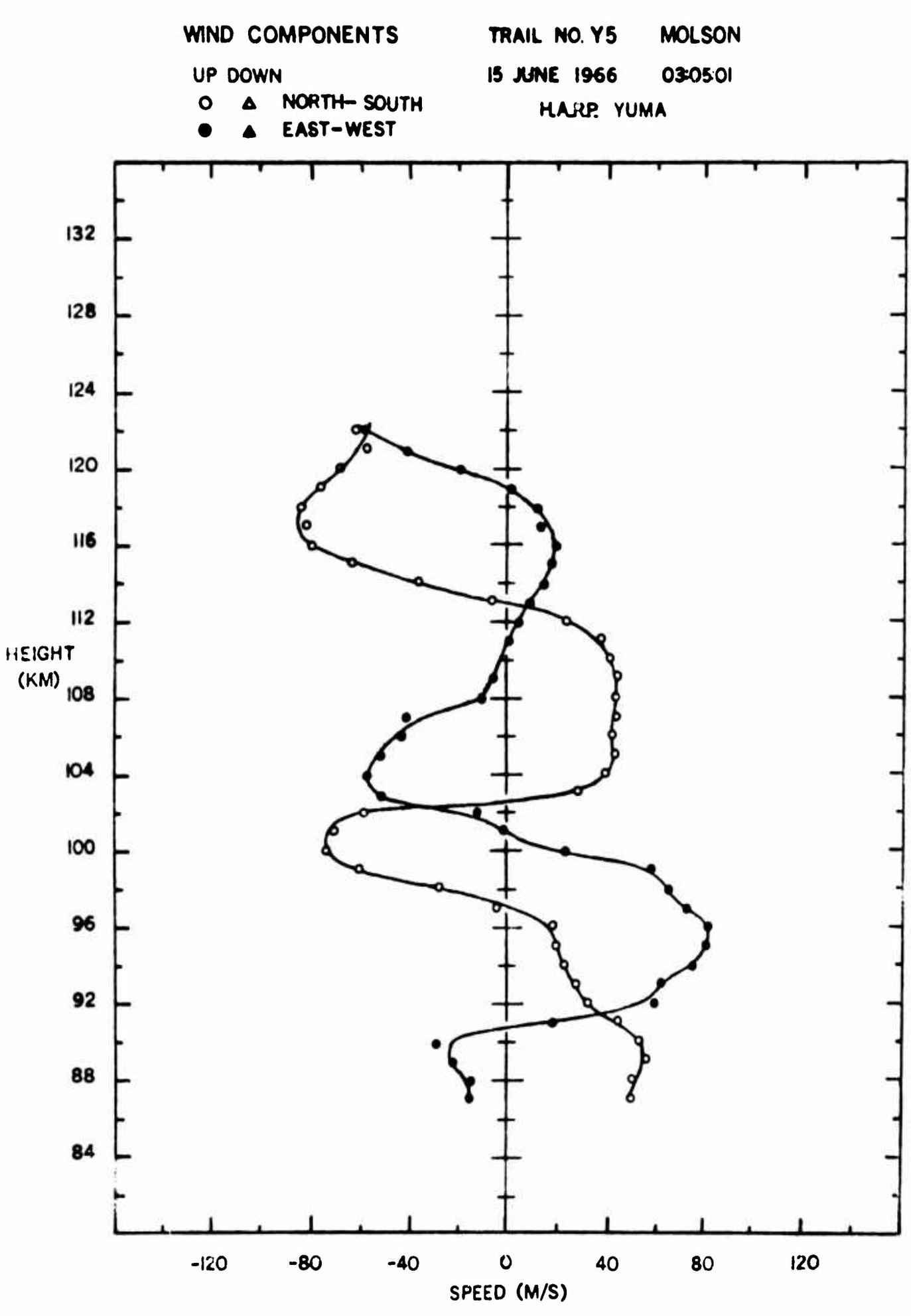
H.A.R.P. YUMA



TRAIL NO. Y5 MOLSON

YUMA 15 JUNE 1966 03-05-01 MST

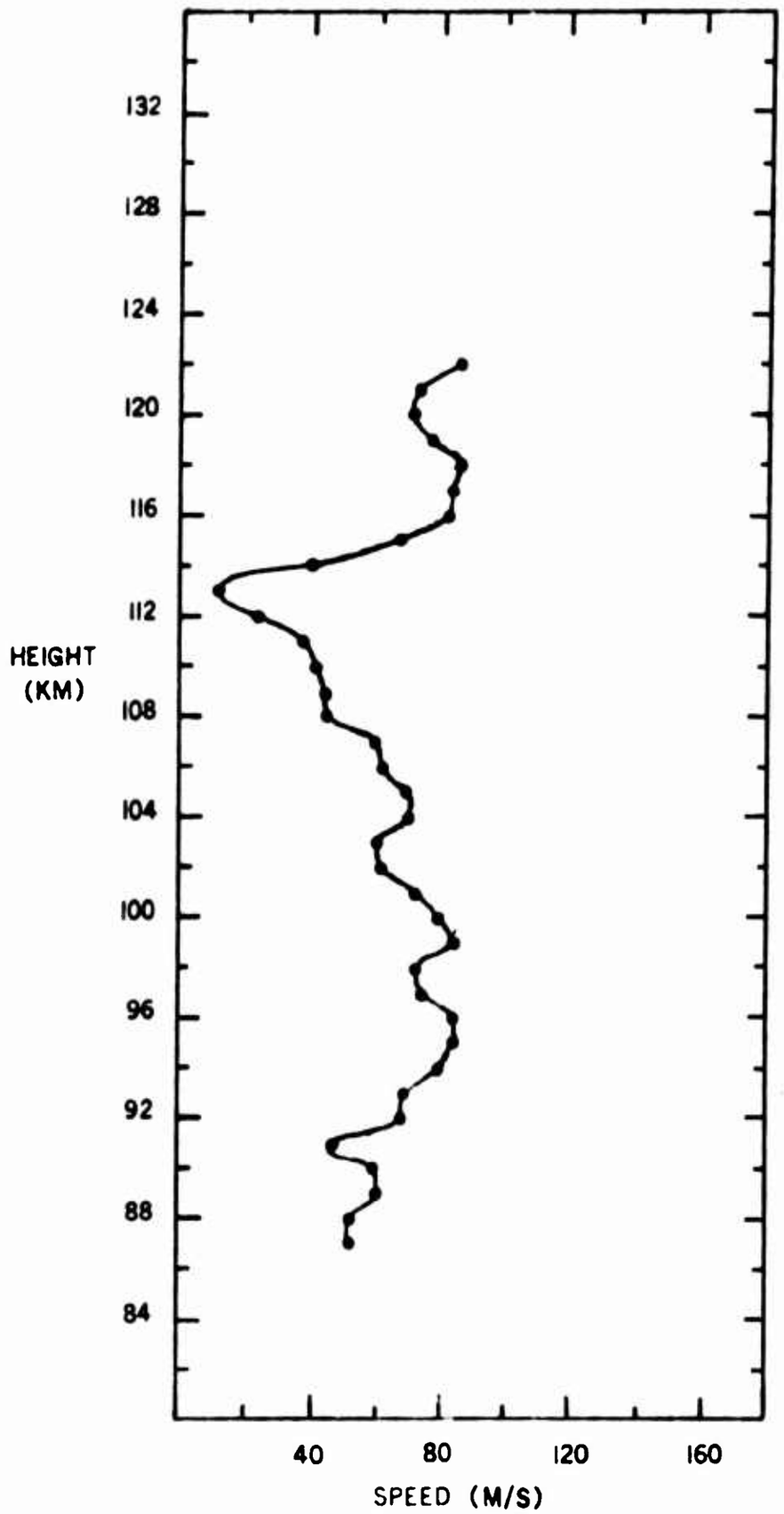
ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
87.0	343.5	50.4	48.3	-14.3	43.3	-25.7
88.0	344.7	51.6	48.8	-13.3	44.0	-24.9
89.0	337.6	59.3	54.8	-22.6	47.6	-35.4
90.0	331.8	58.8	51.8	-27.7	43.4	-39.6
91.0	22.2	46.8	43.3	17.7	46.3	6.5
92.0	62.3	66.7	31.0	59.0	44.6	49.6
93.0	65.9	67.8	27.6	61.9	42.0	53.2
94.0	73.8	78.7	21.9	75.6	39.8	67.9
95.0	76.3	83.1	19.6	80.7	38.9	73.4
96.0	77.9	83.2	17.5	81.4	37.0	74.6
97.0	92.5	73.1	-3.2	73.0	14.9	71.5
98.0	112.6	71.4	-27.4	66.0	-10.3	70.7
99.0	136.1	84.3	-60.7	58.5	-44.4	71.6
100.0	161.4	78.0	-73.9	24.9	-65.5	42.3
101.0	180.5	71.2	-71.2	-0.7	-69.2	16.8
102.0	190.3	60.3	-59.3	-10.8	-60.1	4.1
103.0	298.3	59.0	28.0	-51.9	14.4	-57.2
104.0	304.4	69.6	39.3	-57.4	24.0	-65.3
105.0	309.6	68.3	43.5	-52.6	29.2	-61.7
106.0	314.9	60.5	42.7	-42.8	30.9	-52.0
107.0	316.3	58.3	42.2	-40.2	31.0	-49.4
108.0	347.5	44.0	42.9	-9.5	39.2	-19.8
109.0	354.3	43.9	43.7	-4.3,	41.3	-14.9
110.0	359.5	40.3	40.3	-0.3	39.0	-10.2
111.0	0.8	37.8	37.8	0.5	36.8	-8.8
112.0	10.2	23.5	23.1	4.1	23.4	-1.7
113.0	118.9	11.6	-5.6	10.2	-2.9	11.3
114.0	156.9	39.5	-36.4	15.5	-31.5	24.0
115.0	164.5	66.3	-63.9	17.7	-57.6	32.9
116.0	166.6	82.0	-79.8	19.1	-72.6	38.2
117.0	170.0	83.7	-82.4	14.5	-76.3	34.3
118.0	171.1	85.4	-84.3	13.2	-78.5	33.5
119.0	178.7	76.6	-76.6	1.8	-73.8	20.6
120.0	194.8	70.3	-68.0	-18.0	-70.3	-0.7
121.0	215.4	72.3	-58.9	-41.8	-67.4	-26.0
122.0	223.0	86.1	-63.0	-58.7	-75.5	-41.4


WIND COMPONENTS
TRAIL NO. Y5
MOLSON
UP DOWN
15 JUNE 1966
03:05:01
NORTH- SOUTH
EAST-WEST
HARP. YUMA
132
128
124
120
116
112
HEIGHT (KM)
108
104
100
96
92
88
84
-120
-80
-40
0
40
80
120
SPEED (M/S)

WIND SPEED

● UP TRAIL
▲ DOWN TRAIL

TRAIL NO. Y5 MOLSON
15 JUNE 1966 03:05:01
H.A.R.P. YUMA



WIND DIRECTION

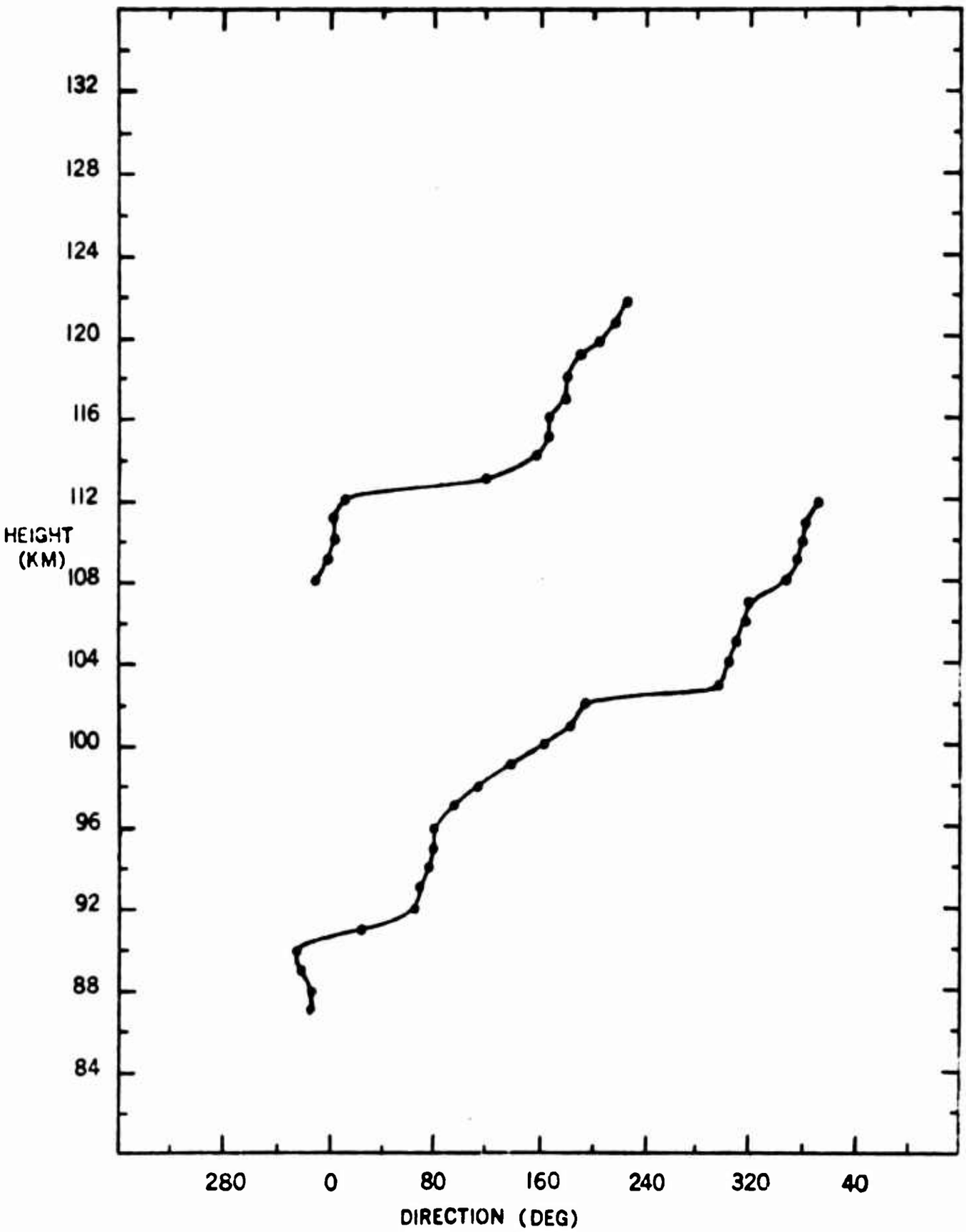
● UP TRAIL

▲ DOWN TRAIL

TRAIL NO. Y5 MOLSON

15 JUNE 1966 03:05:01

H.A.R.P. YUMA



UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
Space Instruments Research, Inc.
Atlanta, Georgia

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
UPPER ATMOSPHERE WINDS FROM GUN-LAUNCHED VERTICAL PROBES (YUMA, 13-15 JUNE 1966)

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*
Robert L. Fuller

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1966	38	37

8a. CONTRACT OR GRANT NO. DA-01-009-AMC-169(X)	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. RDTE 1V014501B53C	BRL Contract 169 Report 4
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT
This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Commanding Officer U.S. Army Ballistic Research Laboratories Aberdeen Proving Ground, Md. 21005

13. ABSTRACT

On the night of 13 June 1966, two luminous trails were produced between 92km and 121km by the release of tri-methyl-aluminum from projectiles fired from a smoothbore sixteen-inch gun located at Yuma Proving Ground, Arizona (114.2°W, 32.8°N). An additional three trails between 85km and 121km were produced on the night of 14-15 June 1966. These trails were photographed by cameras located at Yuma and Gila Bend in Arizona and at Blythe, California, and have been analyzed to yield wind profiles. This report contains the tabulated wind data for all five trails together with plots versus altitude of wind components, wind speed, and wind heading.

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
HARP High Altitude Research Project Ionospheric Winds						